P. KING

MODEL 150 AND 150 R

DC MICRO VOLT-AMMETER

INSTRUCTION MANUAL

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KEITHLEY INSTRUMENTS, INC.
CLEVELAND, OHIO

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SECTION I - INTRODUCTION

The Model 150 Micro Volt-Ammeter is a stable, versatile instrument for measuring extremely low level DC signals. It functions as a voltmeter from one microvolt to one volt full scale, and as an ammeter from one milliampere to one hundred micro-microamperes full scale. It also operates as a DC amplifier with gains up to ten million for driving recorders.

The very low noise level of the Model 150, together with its long term stability make it ideal for many measurements requiring extreme power sensitivity.

Typical applications include measuring the output from strain gages, thermopiles, thermocouples, bolometers, phototubes, ionization chambers, scintillation counters, and barrier layer cells. Other applications are found in cell studies, measurement of electrochemical potentials, electrolytic corrosion studies, molecular weight analysis and Hall effect studies.

In addition to its use as a direct indicator of minute potentials and currents, the Model 150 may also be used as a null detector in Wheatstone or Mueller bridges, or with an external voltage source as a meg-megohmmeter.

An important feature of the instrument is zero suppression up to 100 times full scale, in place of the usual more limited meter zero. This permits measurements of small signals in the presence of large thermal EMF's or other masking DC signals.

SECTION II - SPECIFICATIONS

VOLTMETER SPECIFICATIONS

RANGES: 13 overlapping ranges in 1x and 3x steps from 1 microvolt to 1 volt full scale on a zero-center meter.

ZERO STABILITY: After a one hour warm-up within $\pm$ 0.1 microvolt $\pm$ 2 x 10^{-5} R microvolts per day, where R is the source resistance in ohms.

NOISE: With the input shorted, less than 0.03 microvolt peak to peak (0.006 microvolt RMS). At various source impedances the noise is given by E = 6.5 x 10^{-4} $(R + 2000)^{\frac{1}{2}}$ microvolts peak-to-peak since the ohmic input resistance is added to R, the source resistance.

ACCURACY: 2% of full scale on all ranges.

INPUT AND SOURCE RESISTANCE: As tabulated below unless resistors shunting the input are requested, in which case the input resistance is 100K on the microvolt ranges and 1 megohm on the millivolt ranges. The maximum source resistance specifications on the 1 and 3 microvolt ranges hold with or without shunting input resistors.

RANGE:	Input Resistance Greater than	Maximum Source Resistance
1 microvolt	1 megohm	10k ohms
3 microvolts	3 megohms	30k ohms
10 microvolts	10 megohms	100k ohms
30 microvolts	30 megohms	300k ohms
100 microvolts and above	90 megohms	1 megohm

RESPONSE SPEED: (10 to 90% of full scale). With maximum specified source resistance, less than one second on all ranges except the 1 microvolt range where it is two seconds. With source resistances less than 10% of maximum source resistance, response is within 0.5 second on all ranges, except the 1 microvolt range where it is within 1 second.

VOLTAGE ZERO SUPPRESS: Ranges, Off, plus or minus 10, 100, 1000 and 10,000 microvolts; and 0.1, 1.0, 10.0, 100.0 millivolts corresponding to the MICROVOLTS and MILLIVOLTS positions on the function switch. The accuracy of the suppression ranges is approximately 20% and the stability is such that 100 times full scale may be suppressed.

AMMETER SPECIFICATIONS

RANGES: 15 overlapping ranges in 1x and 3x steps from 10^{-10} to 10^{-3} ampere full scale on a zero center meter.

STABILITY: After one hour warm-up, within plus or minus 2 x 10^{-11} ampere per day.

NOISE: Less than 2 x 10^{-12} ampere peak to peak.

ACCURACY: Plus or minus 3% of full scale on all ranges.

VOLTAGE DROP: 100 microvolts on the millimicroampere ranges, 1 millivolt on the microampere ranges.

INPUT RESISTANCE: Equal to 1 x 10^{-4} divided by current range on microamperes. (Input resistance on the 10^{-3} range is one ohm, rising to one megohm on the 10^{-10} ampere range).

RESPONSE SPEED: One second except on the 10^{-10} range where it is two seconds.

CURRENT ZERO SUPPRESS: A maximum of 100 times full scale zero suppression on any range. Accuracy and stability are the same as for voltage zero suppress.

GENERAL SPECIFICATIONS

RECORDER OUTPUT: Plus or minus 10 volts at five milliamperes for full-scale deflection on any range.

OUTPUT IMPEDANCE: Less than 10 ohms below 1 cps.

60 CPS REJECTION: Greater than 50:1.

INPUT ISOLATION: Negative terminal may be grounded or floating up to plus or minus 400 volts with respect to the case. A link is provided for grounding the negative terminal to the case.

POWER REQUIREMENTS: 117/230 volts, 50 watts, 60 cps only. 50 cps models on special order.

SECTION III - OPERATION

A. OPERATING CONTROLS

The controls of the Model 150 are simple and conveniently placed. Their functions are as follows:

ON-OFF switch is located to the right of the panel meter.

FUNCTION switch selects the function which is to be used: millivolts, microvolts, microamperes or millimicroamperes.

RANGE switch selects the full scale multiplier of the function selected by the FUNCTION switch. Note that the 0.3 and 0.1 positions are to be used in current measurement only.

ZERO SUPPRESS controls consist of the ZERO RANGE switch which selects the coarse range of suppressing voltage in discreet steps and the ZERO SET potentiometer which gives continuously variable fine control including settings through zero.

B. PRELIMINARY SET-UP

Connect the instrument to the power line. Unless otherwise marked the unit may be used on 117 volt, 60 cps line. To convert to 220-volt operation, refer to the MAINTENANCE section. A three-wire line cord is furnished, which grounds the cabinet. If a three-wire receptacle is not available, use the two-pin adapter furnished, and ground the third lead to an external ground.

Set controls as follows:

Function: Millivolts

Range: 1000

Zero Suppress: OFF

Input: Short the input leads together.

C. GENERAL PRECAUTIONS

1. **Source Resistance** - In SECTION II - SPECIFICATIONS under INPUT AND SOURCE RESISTANCE, the maximum source resistance for use with each voltage range is specified. Reasonable operation is possible with source resistances up to ten times greater than those specified, however the measurement will suffer from a considerable decrease in speed of response, and measuring accuracy. If the instrument is left completly open-circuited, the meter will generally drift off scale on any voltage range. On current ranges this does not happen because of the input shunting resistors.

2. Shielding - Since the instrument operates with a modulator frequency of 120 cps, it is not generally sensitive to 60 cps pickup unless it is large enough to overload the amplifier. The pickup may be a source of difficulty when using the amplifier with high impedances on the more sensitive voltage ranges and on the two or three most sensitive current ranges. In these cases it is desirable to shield the leads and the source as completely as possible. In some cases a simple low-pass filter at the input to eliminate frequencies of about 1 cps and above will be helpful. No use is made of an input filter in this instrument since any input series impedance due to the filter will increase the input noise and the thermal drift. When operating above ground, the case of the instrument must be grounded.

3. Thermal EMF - Extreme precautions have been taken in the input circuit to minimize thermal EMF's so that the residual EMF is less than 0.6 microvolt. The material used in the input circuit is pure copper. Any other metal will generate a thermo-couple potential. Lead solder is particularly troublesome. Where thermal EMF's are a problem, soldering should be done with the cadmium-tin solder supplied with the instrument.

4. Input Noise: The noise at the input is a function of input resistance and is approximately given by

$$E = 1.29 \times 10^{-10} (R+2000)^{\frac{1}{2}}$$

where E is the RMS noise, and R is the source resistance. It is assumed that the bandwidth of the instrument is about 1 cps and the temperature is 80°F. If noise is observed, calculate the theoretical noise and compare results. Also bear in mind that only wire-wound resistors approach the ideal resistor. However, if Evanohm or manganin resistors are used, a considerable thermal EMF of the resistor material against copper will be observed.

5. Checking the Zero Point - At low levels, spurious EMF's may be generated simply by contact between the input leads and the terminals under test. If possible, always leave the instrument connected and adjust the zero after establishing a zero reference in the apparatus under test. For example, in bridge measurements, disconnect the bridge exciting voltage; or with a phototube, shield the tube from light.

D. MEASURING VOLTAGE

1. Direct Voltage Measurements - Place the FUNCTION switch at MILLIVOLTS or MICROVOLTS as necessary for the measurement to be taken. Then turn the RANGE switch to more sensitive ranges until the meter gives a usable deflection.

2. Measuring Voltage Variations - Set the FUNCTION switch and RANGE switch to obtain the best deflection of the meter. Use the ZERO SUPPRESS controls as described in B to increase the sensitivity of the meter. Then small changes in a relatively large steady signal may be displayed with a large scale deflection.

3. Measuring Differential Voltages - When measurements are to be made in a circuit where the LOW connection is above ground potential, remove the DISCONNECT LINK from one of its posts on the rear of the cabinet. This disconnects the instrument circuit ground from chassis ground. DO NOT attempt to make such measurements where the low side of the circuit being measured is more than 400 volts above external ground potential.

If a recorder is being used with the instrument in this arrangement, the recorder ground must not be connected to the output ground of the instrument since the low side of the output would no longer be grounded.

E. MEASURING CURRENT

Direct Current Reading - Turn the FUNCTION SWITCH to MICROAMPS or MILLIMICROAMPS, and the RANGE SWITCH to 1000. Connect the instrument to the current source and set the RANGE SWITCH to the range which gives the best deflection of the meter.

Measuring Current Variations - Proceed as above for direct current readings, and then use the ZERO SUPPRESS and ZERO SET as described under B.

F. OTHER APPLICATIONS

1. Null Indicator - The Model 150 makes an extremely sensitive null indicator which may be used in a Wheatstone or Mueller Bridge.

In a Wheatstone Bridge, the Model 150 is connected between the two resistor arms. With the FUNCTION SWITCH on MICROAMPS, and the RANGE SWITCH on 1000, the bridge can be adjusted to give a zero reading on the meter. The instrument can then be set on more sensitive ranges for finer adjustments of the bridge.*

2. Megohmmeter - The Model 150 may be used to measure resistances, utilizing an external voltage source and measuring the current which flows in the unknown.

*If the bridge is arranged so that one terminal of the detector is grounded, the Model 150 may be used as described in D.L. If the detector must be used floating, remove the DISCONNECT LINK at the rear and observe the same precautions as in C.3.

SECTION IV - CIRCUIT DESCRIPTION

The Model 150 is basically a narrow-band chopper amplifier employing negative feedback to stabilize the gain and increase the input impedance.

A. Input Circuit

Zero Stability: The effect of thermal EMF's generated in the input circuitry is reduced to nearly the vanishing point by the use of only copper or silver materials in the input circuit. All solder joints are made with a low thermal cadmium-tin solder. The chopper and chopper transformer employ copper leads. All switching in the input circuit is accomplished with a solid silver switch. Critical resistors in the input circuit are wound of copper wire. The input connector has solid copper spring-loaded contacts.

The input voltage is applied to the moving arm of a 120 cps mechanical chopper. The feedback voltage is connected to the primary center tap of the input transformer. Thus, the difference voltage is applied first across one half of the primary and then, with phase reversal, to the other half. This full wave error signal is stepped up 16 to 1 by the input transformer and applied to the grid of V1, a 6084 low-noise pentode.

B. AC Amplifier

In parallel with the plate load resistor of V1 is a relatively high Q, 120 cps resonant circuit which narrows the bandwidth and reduces spurious signals.

V2 and V3, EF86 pentodes, further amplify the chopped error signal which is then demodulated synchronously by germinium diodes D1 and D2.

To obtain the 120 cps demodulator driving signal, use is made of the ripple frequency from a bridge rectifier circuit operating from the line voltage. The ripple is connected to the primary of the demodulator driver transformer.

C. DC Amplifier

The demodulated signal is applied to the grid of V4. V4, V5, and V6 form the dc amplifier and output cathode follower which add further forward gain to the system and supply output power. Feedback around V4, V5 and V6 multiplies the effective capacitance of demodulator filter capacitor C113 by about 1000. This yields the large equivalent capacitance necessary to smooth the demodulated error signal. Because of the feedback, spurious noise in the dc stages outside the pass band of the whole amplifier are effectively degenerated.

D. Zero Suppression

A low-current ± 10 volt supply is derived from the main dc supplies using 10-volt zener diodes. Potentiometer R174 may be set at any voltage from -10 to +10 volts, this voltage being applied through appropriate dropping resistors to the feedback point to achieve zero suppression. The potentiometer is the front panel control marked ZERO SET, while switch SW3, which determines the portion fed back, is labeled ZERO RANGE.

E. Other Controls

Three controls are set at the factory and should require only infrequent attention by the user.

R118 is an internal control marked DC AMP BAL. It is used to zero the DC amplifier, i.e., to set the output voltage to zero when the demodulator output is zero. This is not very critical since an unbalance will simply be fed back to the input to produce a small error signal to correct itself. R127 is marked CAL. This is the variable portion of the meter multiplier resistance to allow for meter-to-meter sensitivity differences.

R177, marked CURRENT BALANCE, may be set at some voltage which will cause a current to flow through R175 to the chopper arm. This current is used to compensate for a small generated "chopper current" which would otherwise flow in the input circuit. This "chopper current" differs from chopper to chopper but is fairly stable for long periods of time. Its effect on any current range could be removed with the ZERO SUPPRESS controls, but the Current Balance method used here gives an effective zero input current for all ranges.

F. Power Supply

A standard half-wave rectifier followed by an R-C filter is used to supply unregulated B+ and B- to the output cathode follower.

The unregulated B- is regulated to -150 volts in V7, OA2, and is used for the negative returns for the dc amplifier.

Unregulated B+ is fed to the plate of V8, 12B4A, the series tube in a 225-volt electronic regulator. The output voltage from this regulator is divided by R510 and R511 and compared to reference tube V9, a 5651. The difference signal is amplified by cascode amplifier V10, a 12AX7, and applied to the grid-cathode circuit of the series tube. This regulated 225 volts supplies B+ directly to the dc amplifier, through a decoupling filter (R176, C110) to the second and third ac amplifier stages, and through another decoupling filter (R103, C104) to the first ac amplifier stage.

Regulated B+ and B- also supply currents to the 10 volt zener diodes which are used for zero suppression. This gives two-stage regulation for these very critical voltages.

The first two ac amplifier filaments and the first dc amplifier filaments are driven by a bridge-rectified 6-volt d.c. supply. The R-C filter sections R512, C507, R513, C508, insure low ripple.

Except for occasional tube or chopper replacement, very little maintenance is required by the Models 150 and 150R. Components are operated well below rating and solid-state devices are employed where possible to achieve long, trouble-free service.

Certain portions of the input circuit are wired using copper wire and special cadmium-tin solder. These special joints are painted red. If, for any reason, these joints must be unsoldered or re-soldered, USE ONLY CADMIUM-TIN SOLDER AND A COPPER-TIPPED SOLDERING IRON WHICH HAS NEVER BEEN USED WITH ORDINARY LEAD-TIN SOLDER. A small spool of cadmium-tin solder is supplied with each instrument.

What may seem to be circuit failure in the Micro Volt-Ammeter is quite often found to be an unusual condition in the entire test set-up. Therefore, before trouble-shooting the instrument, check to see whether it operates correctly with:

1. All other circuitry disconnected.
2. Input shorted (with copper leads).
3. Power line voltage and frequency correct.

If the difficulty persists, the following systematic procedure may be employed to determine the fault.

TROUBLE-SHOOTING

Reference is made to the Schematic Diagram, DR 12186-D, and the Voltage-Resistance Diagram enclosed at the rear of the manual.

To begin trouble-shooting, short the input terminals, strap chassis ground to LO with the link provided, and switch ZERO RANGE to OFF. A zero offset of a few tenths of a microvolt is normal. On current functions with the input terminals open but shielded, it should be possible to set zero current with the CURRENT BALANCE control at the rear of the instrument.

EXCESSIVE OUTPUT NOISE (INPUT TERMINALS SHORTED)

Short the input grid of the dc amplifier, pin 7 of V4, to ground. If this stops the noise, it is being generated in the ac amplifier. Unfortunately, because of the very low signal levels involved, noise in the ac amplifier is difficult to trace by other than the substitution method. Most logical noise sources are in the chopper. To replace the chopper, unplug the cap at the top, and unscrew the three thumb-screw nuts which clamp the chopper leads. Unscrew the two chopper mounting screws and lift out the chopper. When inserting the new chopper, make sure that the chopper leads are pressed against the copper terminals and that the insulating washers are between the leads and the thumb-screw nuts. Observe color-coding on the leads.

If the noise persists after shorting the amplifier input, the noise is being generated in the dc amplifier or power supply. A stage-by-stage search should reveal the source.

OUTPUT NOT ZERO (INPUT TERMINALS SHORTED)

Be sure that ZERO RANGE is set to OFF. Short the dc amplifier input grid, pin 7 of V4, to ground. Use the DC AMP BAL Control to set the output to zero. If this cannot be done, the dc amplifier or power supply are at fault. If it can be set to zero, the trouble may be in the ac amplifier or demodulator circuit.

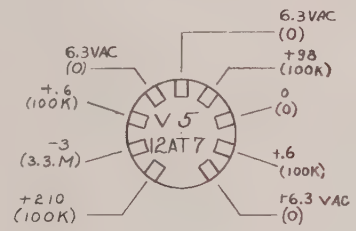
a. Power Supply - B- should be about -225 on pin 1 of V8, and B- should be -150 on pins 2, 4 or 7 of V7. If V7 is not firing, correct the fault in the unregulated B-. If -225 is not present, check for unregulated B+ (about 340 volts) at the plate pin 9 of V8. If the unregulated B+ is all right, check the tube pin voltages of V8, V9, and V10 to locate the faulty tube or part.

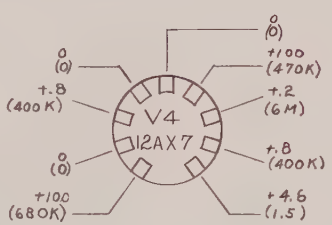
b. AC Amplifier - Remove the output tube (V6) and clip pin 1 of the output connector to ground. Place the FUNCTION switch on MILLIVOLTS, and turn the ZERO SET and ZERO RANGE controls full clockwise. This puts a large dc error signal across the chopper and input transformer. Use an oscilloscope to check for the presence of 120 cps at the primary of the input transformer (the two outside terminals on the chopper terminal block). Absence of signal means chopper failure (or much less likely, shorted input transformer). Listen for audible chopper action and check chopper drive, if necessary.

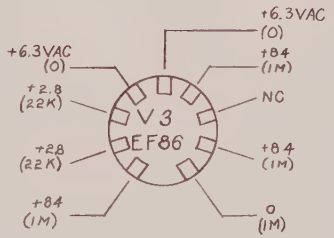
If the 120 cps signal is present, check stage-by-stage throughout the ac amplifier, reducing the input signal as desired by backing off the ZERO RANGE and/or ZERO SET controls, until the failure is discovered.

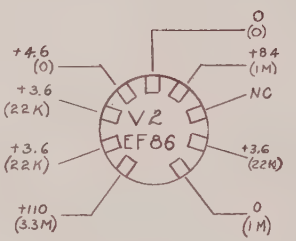
d. Demodulator Circuit - Check for presence of about 80 volts RMS at the secondary of the demodulator transformer (at the ends of R113 and R114).

The tests outlined above will not suffice to pin-point every fault which may exist. They should, however, lead to the correction of common failures. In the event that troubles cannot be corrected by these means, or the user finds it more expedient, the unit may be returned to the factory for repair and recalibration at a nominal cost.









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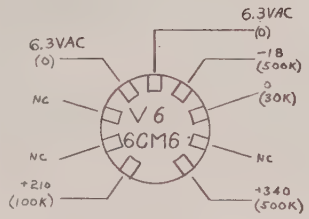
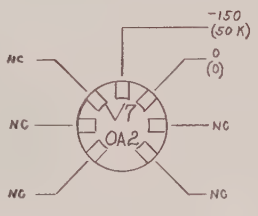
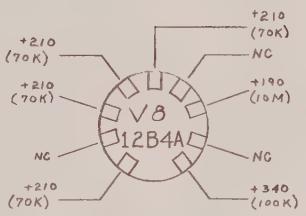
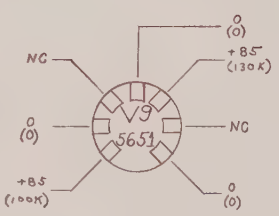
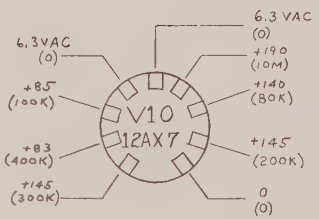






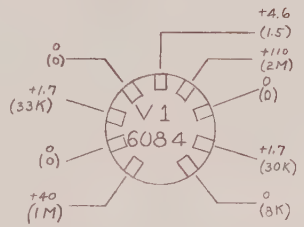




MODEL 150
VOLTAGE AND RESISTANCE CHART

MEASUREMENTS FROM TUBE PIN TO GROUND USING VTVM WITH 10 MEGOHM INPUT RESISTANCE. FUNCTION SWITCH AT MILLIVOLTS, INPUT SHORTED, RANGE SWITCH AT 1000, ZERO SUPPRESS OFF.

ALL READINGS ARE APPROXIMATE:
RESISTANCES ARE GIVEN IN OHMS; K=1000; M=MEGOHMS



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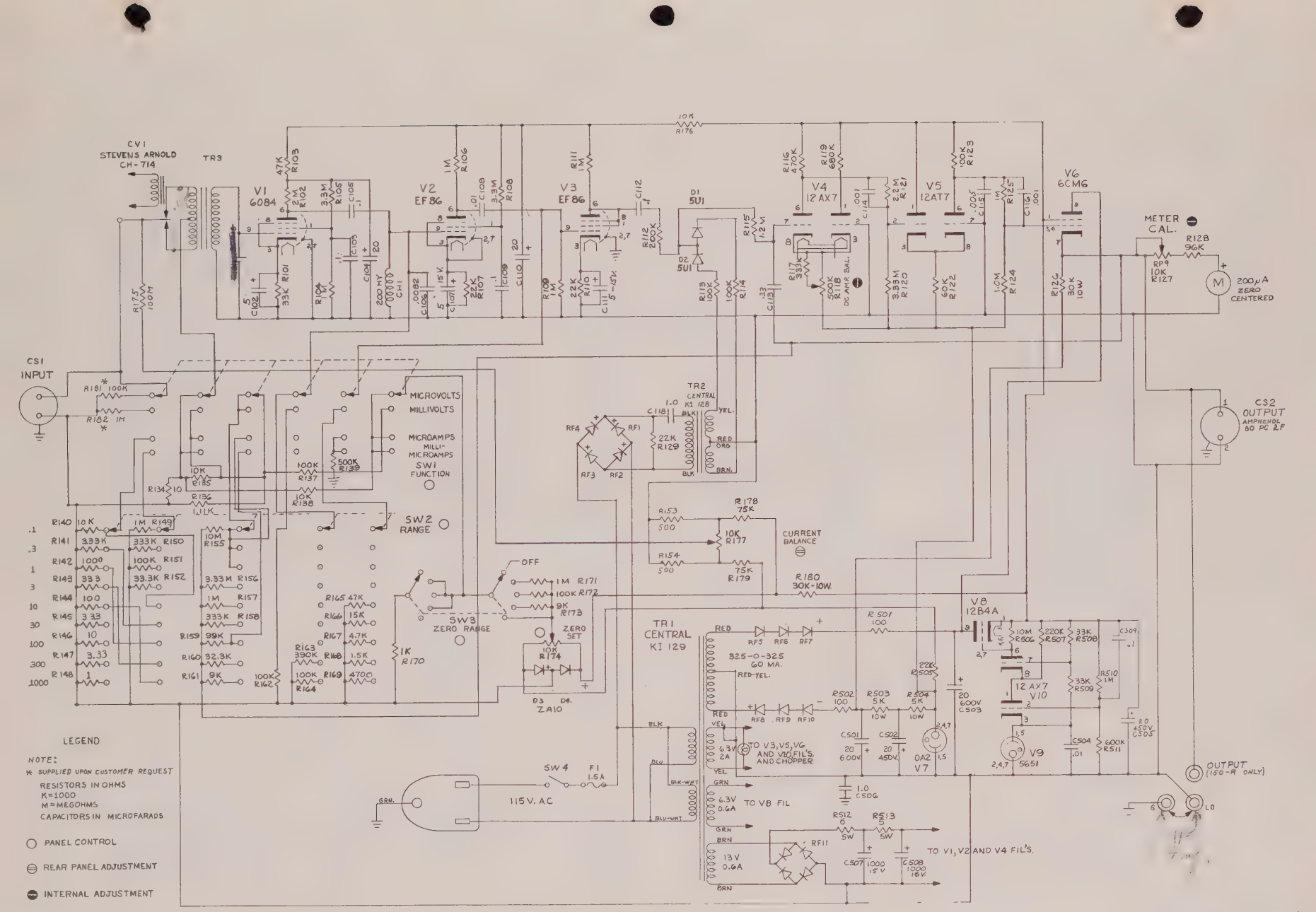
DR 12393 - C



MODEL 150
SCHEMATIC

KEITHLEY INSTRUMENTS
CLEVELAND, OHIO

DR 12188 D

Circuit Des.	Description	Part No.
C101	Capacitor, silver mica, 150mmf. 500 VDCW	C21-150
C102	Capacitor, tubular, electrolytic, 5mfd, 15 VDCW	C11-5
C103	Capacitor, metalized paper 0.1mfd. 200 VDCW	C18-.1
C104	Capacitor, tubular, electrolytic, 20mfd. 450 VDCW	C8-20L
C105	Capacitor, mylar dielectric, .1mfd. 400 VDCW	C30-.1
C106	Capacitor, mylar dielectric for 50 cycle model .0082mfd. 1%, 100 VDCW	C45-.0082
C107	Same as C102	
C108	Capacitor, ceramic disc, .01mfd. 600 VDCW	C22-.01
C109	Same as C103	
C110	Same as C104	
C111	Same as C102	
C112	Same as C105	
C113	Capacitor, mylar dielectric, .333mfd. 200 VDCW	C29-.333
C114	Capacitor, ceramic disc, .001mfd. 600 VDCW	C22-.001
C115	Capacitor, ceramic disc, .005mfd. 600 VDCW	C22-.005
C116	Same as C114	
C118	Capacitor, metalized paper, 1.0mfd. 200 VDCW	C18-1.0
C501	Capacitor, tubular, electrolytic, 20mfd. 600 VDCW	C35-20
C502	Same as C104	
C503	Same as C501	
C504	Same as C108	
C505	Same as C104	
C506	Capacitor, mylar dielectric, 1.0mfd. 400 VDCW	C30-1.0
C507	Capacitor, tubular, electrolytic, 1000mfd. 12 VDCW	C11-1000
C508	Same as C507	
C509	Same as C105	
CH1	Choke, 200 HY., 120 cps Hi Q	CH1
CS1	Connector, input, special	
CS2	Connector, output, amphenol 80 PC 2F	CS 32
CU1	Chopper, frequency doubling, special 60 cycle	CV2
	50 cycle	CV3
D1	Diode, Selenium, International Rect. Corp. 501	RF 15
D2	Same as D1	
D3	Diode, Zener, Hoffman Semiconductor ZA10	DZ-ZA10
D4	Same as D3	
F1	Fuse, 1½A, 3AG (110V), Fuse, 1A, 3AG (220V)	FU8-FU-7
M	Meter, Panel, 200 micro amp zero center	ME 14
R101	Resistor, composition, 33K, 10%, ½W	R1-33K
R102	Resistor, deposited carbon, 2 meg, 1%, ½W	R12-2M
R103	Resistor, composition, 47K, 10%, ½W	R1-47K
R104	Resistor, composition, 1 meg, 10%, ½W	R1-1M
R105	Resistor, deposited carbon, 3.33 meg, 1%, ½W	R12-3.33M
R106	Resistor, deposited carbon, 1 meg, 1%, ½W	R12-1M

Circuit Des.	Description	Part No.
R107	Resistor, composition, 22K, 1%, ½W	R1-22K
R108	Resistor, composition, 3.3 meg, 10%, ½W	R1-3.3M
R109	Same as R104	
R110	Same as R107	
R111	Same as R106	
R112	Resistor, deposited carbon, 200K, 1%, ½W	R12-200K
R113	Resistor, deposited carbon, 100K, 1%, ½W	R12-100K
R114	Same as R113	
R115	Resistor, deposited carbon, 1.2meg, 1%, ½W	R12-1.2M
R116	Resistor, deposited carbon, 470K, 1%, ½W	R12-470K
R117	Resistor, deposited carbon, 333K, 1%, ½W	R12-333K
R118	Potentiometer 500K ohms	RP5-2
R119	Resistor, deposited carbon, 680K, 1%, ½W	R12-680K
R120	Same as R105	
R121	Resistor, deposited carbon, 2.2 meg, 1%, ½W	R12-2.2M
R122	Resistor, deposited carbon, 60K, 1%, ½W	R12-60K
R123	Same as R113	
R124	Same as R106	
R125	Same as R106	
R126	Resistor, wirewound 30K, 10%, 10W	R5-30K
R127	Potentiometer, 10K ohms	RP9-10K
R128	Resistor, deposited carbon, 96K, 1%, ½W	R12-96K
R129	Resistor, composition, 22K, 10%, 2W	R3-22K
R134	Resistor, special, copper wirewound 10 ohms, 1%	R18-18-10
R135	Resistor, special, copper wirewound 10K ohms, 1%	R18-18-10K
R136	Resistor, deposited carbon, special, 1.11K, 1%, ½W	R38-1.11K
R137	Resistor, deposited carbon, special, 100K, 1%, ½W	R38-100K
R138	Resistor, special, copper wirewound, 10K ohms 5%	R18-19-10K
R139	Resistor, deposited carbon, 500K, 1%, ½W	R12-500K
R140	Resistor, deposited carbon, 10K, 1%, ½W	R12-10K
R141	Resistor, deposited carbon, 3.33K, 1%, ½W	R12-3.33K
R142	Resistor, deposited carbon, 1K, 1%, ½W	R12-1K
R143	Resistor, deposited carbon, 333 ohms, 1%, ½W	R12-333
R144	Resistor, deposited carbon, 100 ohms, 1%, ½W	R12-100
R145	Resistor, deposited carbon, 33.3 ohms, 1%, ½W	R12-33.3
R146	Resistor, deposited carbon, 10 ohms, 1%, ½W	R12-10
R147	Resistor, deposited carbon, 3.33 ohms, 1%, ½W	R12-3.33
R148	Resistor, deposited carbon, 1.0 ohms, 1%, ½W	R12-1.0
R149	Same as R106	
R150	Same as R117	
R151	Same as R113	
R152	Resistor, deposited carbon, 33.3K, 1%, ½W	R12-33.3K
R153	Resistor, deposited carbon, 500 ohms, 1%, ½W	R12-500
R154	Same as R153	
R155	Resistor, deposited carbon, 10 meg, 1%, 1W	R13-10M
R156	Same as R105	
R157	Same as R106	
R158	Same as R117	
R159	Resistor, deposited carbon, 99K, 1%, ½W	R12-99K
R160	Resistor, deposited carbon, 32.3K, 1%, ½W	R12-32.3K
R161	Resistor, deposited carbon, 9K, 1%, ½W	R12-9K
R162	Resistor, composition, 100K, 10%, ½W	R1-100K
R163	Resistor, composition, 390K, 10%, ½W	R1-390K
R164	Same as R162	

Circuit Des.	Description	Part No.
R165	Resistor, composition, 47K, 10%, ½W	R1-47K
R166	Resistor, composition, 15K, 10%, ½W	R1-15K
R167	Resistor, composition, 4.7K, 10%, ½W	R1-4.7K
R168	Resistor, composition, 1.5K, 10%, ½W	R1-1.5K
R169	Resistor, composition, 470 ohms, 10%, ½W	R1-470
R170	Resistor, deposited carbon, 1K, 1%, ½W	R12-1K
R171	Same as R106	
R172	Same as R113	
R173	Same as R161	
R174	Potentiometer, 10 turn, 10K	RP4-10K
R175	Resistor, deposited carbon, 100 meg, 1%, 2W	R14-100M
R177	Same as R127	
R178	Resistor, deposited carbon, 75K, 1%, ½W	R12-75K
R179	Same as R178	
R180	Same as R126	
R181	Resistor wirewound, special, customer request only	R18-21-100K
R182	Resistor, deposited carbon, 1 meg, 1%, ½W, customer request -	R12-1M
R501	Resistor, composition, 100 ohms, 10%, 2W	R3-100
R502	Same as R501	
R503	Resistor, wirewound, 5K, 10%, 10W	R5-5K
R504	Same as R503	
R505	Resistor, composition, 22K, 10%, 2W	R3-22K
R506	Resistor, composition, 10 meg, 10%, ½W	R1-10M
R507	Resistor, deposited carbon, 220K ohms, 1%, ½W	R12-220K
R508	Same as R101	
R509	Same as R101	
R510	Same as R106	
R511	Resistor, deposited carbon, 600K, 1%, ½W	R12-600K
R512	Resistor, wirewound, 6 ohms, 10%, 5W	R4-6
R513	Resistor, wirewound, 5 ohms, 10%, 5W	R4-5
RF1 thru RF10	Rectifier, selenium, 130v, 65ma	RF8
RF11	Rectifier bridge, 26 volt, 600ma	RF7
SW1	Function switch, 4 pole, 4 position	SW56
SW2	Range switch, 9 position	SW54
SW3	Zero suppress, zero range 5 position	SW58
SW4	Power switch, D.P.D.T.	SW14
TR1	Power transformer Central KI-129	TR27
TR2	Demodulator transformer Central KI-128	TR26
TR3	Input transformer, James C1835 special	TR28
	Pilot lamps (2) 6.3v, 0.15 amps G.E. type 47	PL4
V1	Vacuum tube, type 6084	EV6084
V2	Vacuum tube, type EF86	EV-EF86
V3	Same as V2	
V4	Vacuum tube, type 12AX7	EV-12AX7
V5	Vacuum tube, type 12AT7	EV-12AT7
V6	Vacuum tube, type 6CM6	EV-6CM6
V7	Vacuum tube, type OA2	EV-OA2
V8	Vacuum tube, type 12B4A	EV-12B4A
V9	Vacuum tube, type 5651	EV-5651
V10	Same as V4	

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